

VLA IMAGING OF PROTOPLANETARY ENVIRONMENTS

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Annual Report

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We continue to use the Very Large Array (VLA) of the National Radio Astronomy Observatories (NRAO) to make high resolution images of thermal emission in the protoplanetary environment of nearby young stars.

The VLA provides two unique capabilities. First, the angular resolution for imaging thermal emission is unmatched by any other facility. For the A array, the synthesized beam at a wavelength of 7 mm corresponds to a linear scale similar to the orbital radius of Jupiter at the distance of nearby dark clouds like Taurus. Second, the long millimeter wavelengths accessible to the VLA are particularly advantageous at this high resolution since the emission is (almost) entirely optically thin and probes the full disk column, including the innermost regions that remain opaque to shorter wavelengths.

We list accomplishments of the past year and plans for next year:

- We successfully obtained data on three candidate disk systems using the VLA in the A configuration that provides the maximum angular resolution, better than 40 milliarcseconds, or 5 AU at the distance of the Taurus dark cloud. These observations were able to take advantage of the outfitting of additional antennas with 7 mm receivers (from 16 in Fall 1999 to 22 in Fall 2000), and resulted in maps with the best 7 mm sensitivity yet achieved (~ 0.1 mJy). All three Taurus disk sources observed show detectable emission, directly probing the planet forming zone of the circumstellar environment.
- We made the first 7 mm astronomical observations with the new optical fiber link from the VLA to the Pie Town antenna of the VLBA, which effectively doubles the angular resolution. These results represent the culmination of three years of preparatory work from more compact configurations. Figure 1 shows the results for DG Tau, the most interesting system imaged to date, with images made at two resolutions, about 55 mas and 35 mas (insert). The lower resolution image clearly shows the inner part of the dusty disk, extended perpendicular to the direction of the optical jet indicated by the arrow. The ellipses to the right show the scale of the orbits of the giant planets in our Solar System. The higher resolution image shows only the higher brightness emission, with a very interesting asymmetry whose origin is

unclear but may be related to the outflow, to the condensation of a protoplanet from the disk, or perhaps to the dynamical effect of an already formed protoplanet. Note the detailed higher resolution image requires the longer baselines of the Pie Town link. It's possible that a fraction of the emission in the higher resolution image comes from ionized gas and not dust. Since the dynamical timescales at this scale are short for either orbital motion or outflow (years), we will be able to discriminate among some of the many possibilities for the structure with a second epoch image. We have proposed for additional observations in the next A configuration in 2002.

- We presented the first results from our high resolution data on T Tauri disks at three forums: (1) ESO Workshop on The Origins of Stars and Planets (Garching, Germany), (2) NASA Ames Workshop on Young Stars Near Earth (Mountain View, CA), and (3) an invited colloquium at the University of California at Santa Cruz (Santa Cruz, CA). Our primary task for the next year is to complete and publish a full analysis of these data, in particular the constraints on disk surface densities, which are interesting from the point of view of accretion physics and initial conditions for planet formation.
- We published a detailed theoretical model of the 10 Myr old TW Hya system that uses VLA data for important observational tests, in collaboration with Nuria Calvet (Smithsonian Astrophysical Observatory). This model requires a clearing of disk material within a few AU of star, possibly due to the formation of a planet, and substantial grain growth.
- We published the first results of our VLA 7 mm observations of Herbig Ae/Be stars in collaboration with Leonardo Testi (Arcetri Observatory) that suggest substantial grain size evolution. We have proposed additional higher resolution VLA 7 mm observations of one system, CQ Tau, to resolve the disk emission.

References

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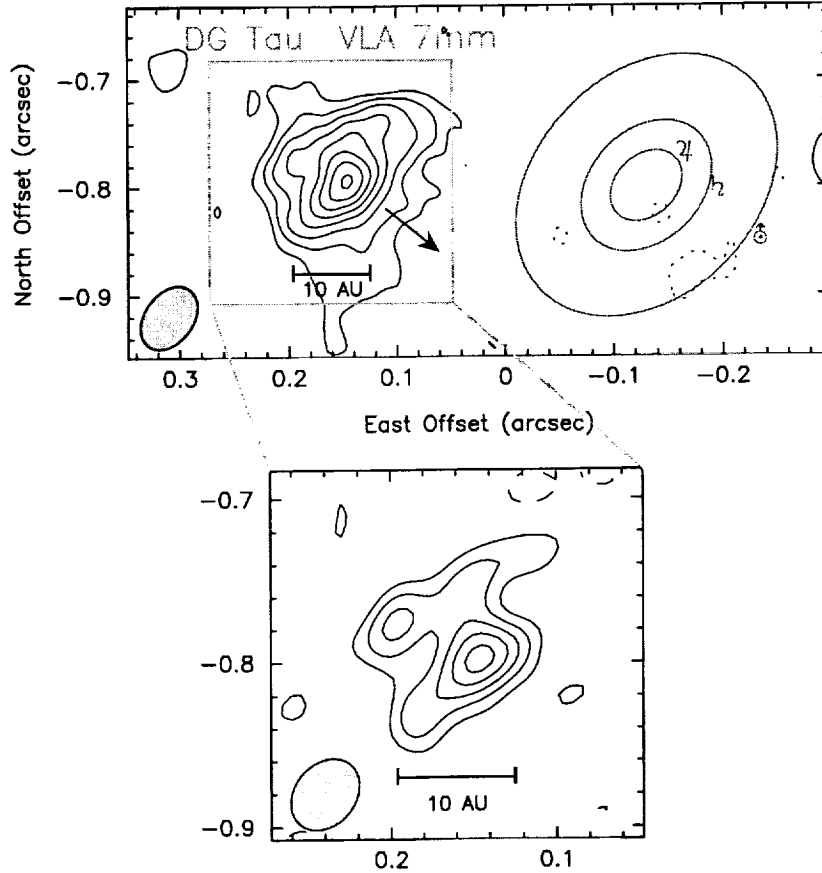


Fig. 1.— 7 mm continuum images of the DG Tauri system with two resolutions from the VLA & VLBA Pie-Town link. The upper panel shows the inner part of the dust disk; the arrow indicates the position angle of the optical jet observed at larger scales. The ellipses to the right show the orientation of the disk, and the spacings of the ellipses correspond to orbits of the giant planet orbits in our Solar System. Contours levels are $(2, 3, \dots) \times 0.12$ mJy (upper) and 0.14 mJy (lower). The synthesized beam size in the higher resolution image is ~ 35 mas (5 AU at 140 pc distance).